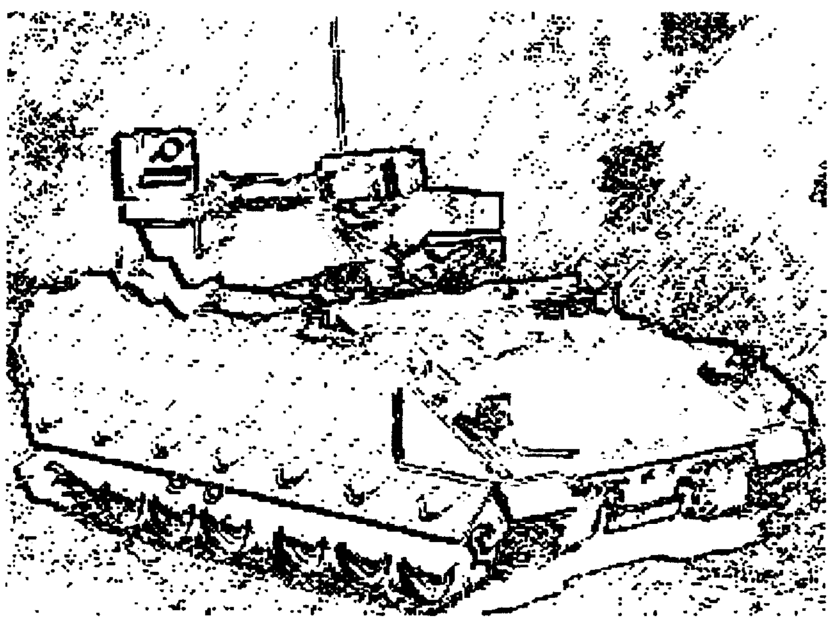
Engineering and Applied Science

Dual Agent Approaches to Crew Compartment Explosion Suppression



Report I. Fixture Development and Proof of Concept Testing

Prepared by:

Douglas S. Dierdorf, Ph.D.

Applied Research Associates, Inc.
215 Harrison Ave
Panama City, FL 32401
Phone: (850) 914-3188
Fax: (850) 914-3189
Electronic Mail Address: ddierdorf@ara.com

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I. Background

The work described here demonstrates a zero-ODP, zero-GWP approach to crew compartment explosion suppression at a "Proof of Concept" level. This concept uses a combination of dry chemical and water to overcome the difficulties with gaseous halon substitutes for this application. The crew compartment explosion suppression application in armored combat vehicles has been the single, most difficult application for halon replacement. In cooperation with the Vehicle Systems division of Pacific Scientific we are pursuing a novel and potentially low cost solution to this problem for new combat vehicle designs.

Dry chemical fire suppressants have been successfully utilized in commercial explosion suppression applications, but have not been applicable in the crew compartment application because of the "white-out," low visibility condition which exists for a considerable time after discharge. Likewise, water mist systems have been shown to be effective in suppressing explosions but have required unacceptably high energy distribution means to be dispersed in sufficient quantity at small enough droplet sizes in the short time required to suppress a crew compartment explosion.

We have demonstrated successful distribution of dry chemical agent in the time and volume required for explosion suppression using current military vehicle technologies (valves, bottles, etc.) In this effort we demonstrate a system which would suppress the fuel mist deflagration in the crew compartment using dry chemicals followed by a water mist wash-down to restore acceptable operational conditions.

II. Methods

The approach taken in this work has been as follows:

1. Develop specification for a test fixture which reproduces the volume and shape of the Crew Compartment Test Fixture operated by the Army Test Center, Aberdeen Proving Grounds, MD.
2. Construct this test fixture and provide for data acquisition and controls to discharge the agent and bottles in a specified sequence and timing. This same system then records agent discharge time and produces a record of discharge pressure.
3. Conduct initial tests to show the effectiveness of the concept and identify important parameters for optimization.

III. Fixture Design and Construction

Sketches of the test fixture at Aberdeen Proving Grounds were provided by Mr. Stanley Polyanski, Test Director, Aberdeen Test Center. Design factors were confirmed by personal inspection of the fixture. Using these sketches, ARA built a wood and plexiglass test fixture which carefully reproduces the shape and dimensions of the live fire test fixture.

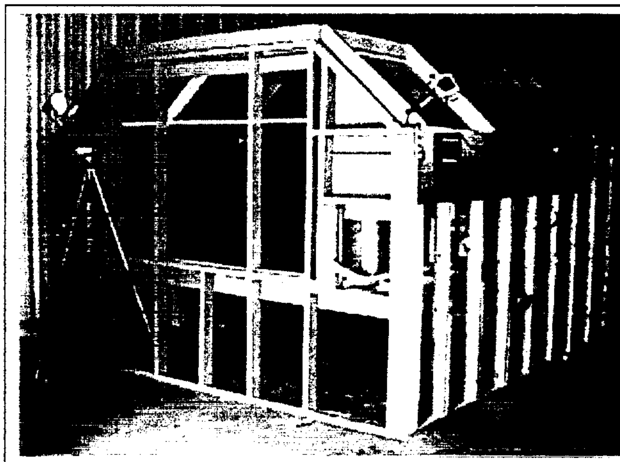


Figure 1. Front ¾ View of the Completed Test Fixture

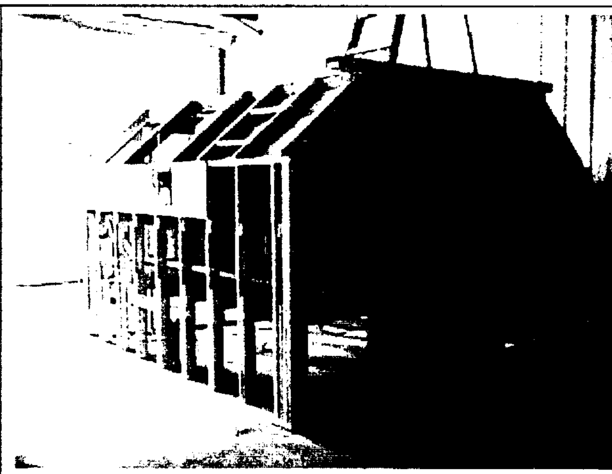


Figure 2. Rear ¾ View of the Completed Test Fixture.

The finished fixture is shown in Figure 1 and Figure 2. There are several key features, which were incorporated for these tests:

1. The front wall, and a large portion of the top were fitted with 1/8th inch Lucite windows.
2. Bottle mounting positions were reinforced to provide sufficient strength to resist damage caused by high pressure, high rate discharges. See Figure 3.
3. A video camera is suspended from the ceiling of the building to provide a map view of each test.

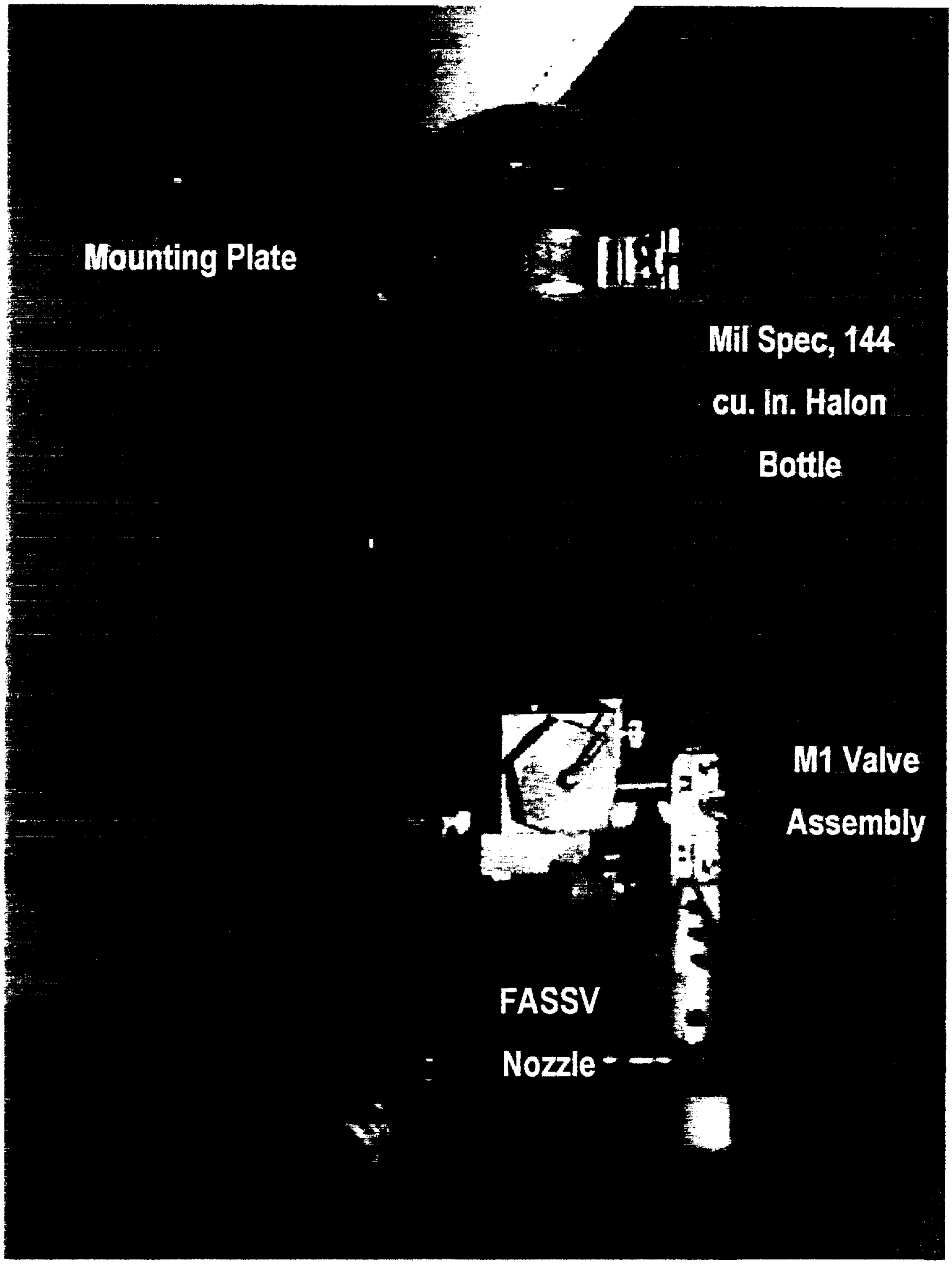


Figure 3. Fire bottle mounted in the Test Fixture.

Mounting plates on both sides of the fixture wall provide reinforcement to contain the recoil force of the bottle discharge. The bottles, valves, and nozzles are all standard issue on various Army vehicles. The system is therefore "typical" rather than a specific vehicle system.

III.A. Data Acquisition, Experiment Control

Data acquisition and experiment controls are implemented with a LabView® 5.0 program on a Gateway 486-

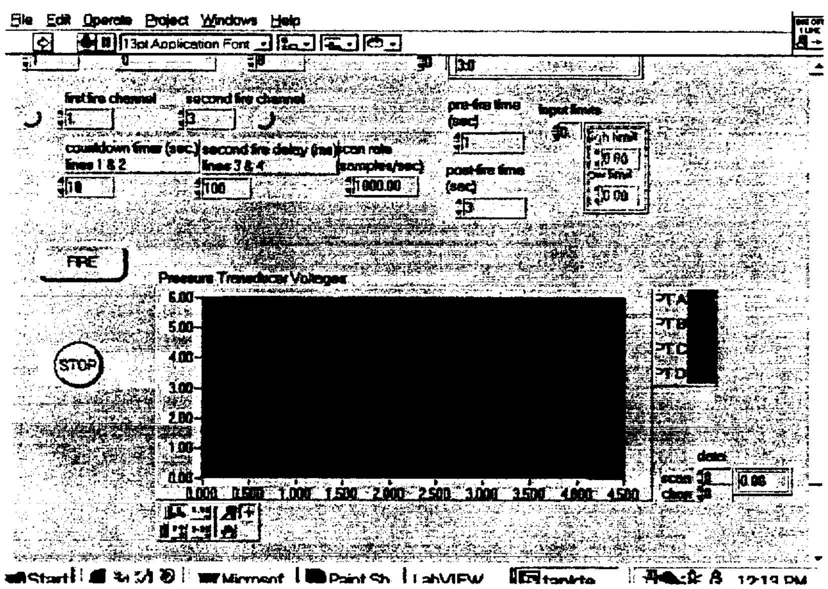


Figure 4. Screen Shot

66 computer upgraded with a Pentium processor and 48 Mb of DRAM memory. The data acquisition and control hardware is a National Instruments board, model number PC-LPM-16PNP. Figure 4. provides a view of the program control screen.

The system provides discharge signals to the bottles in pretimed sequences. For example, a powder bottle can be discharged at time (0) and one or more water bottles discharged at a later time, in milliseconds. In addition, a pressure transducer is attached to each bottle to record internal pressure as a function of time. The resolution of this data is approximately 5 psi at 1000 Hz.

IV. Test Results

At this point, there have been a total of nine discharge tests as described in the attached test summary sheets.

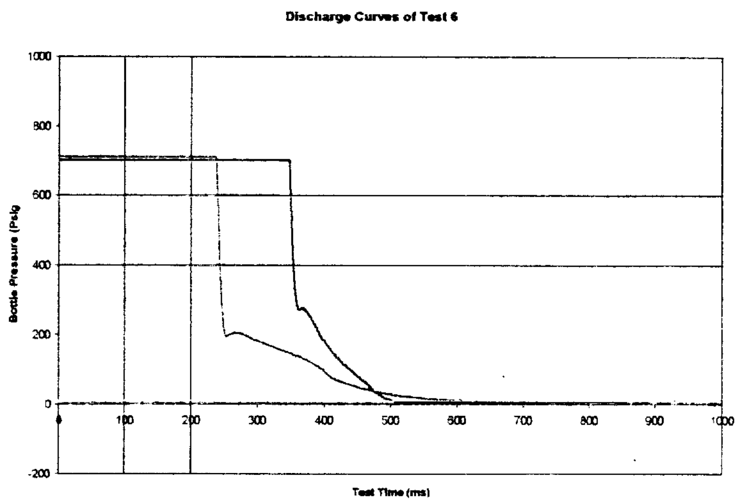
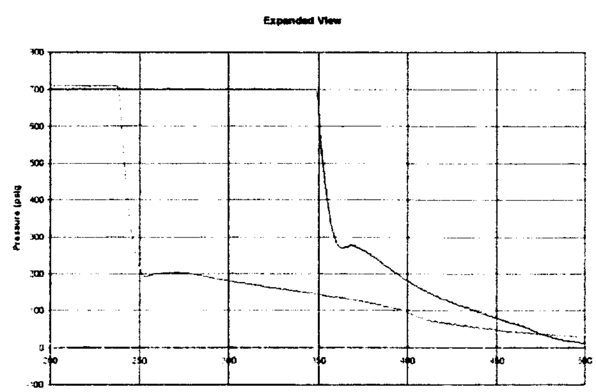


Figure 5. Discharge Example

Figure 5 illustrates typical discharge behavior for the 5 lb. Bottle and Valve combination. It should be noted that the pressure transducers are attached to the Schrader fill valve and therefore may not accurately reproduce absolute pressures. The nominal delay between discharges is 100 ms (106 observed). This small variation is a



result of the interupt driven processing in Windows 95 which makes precise timing of digital controls impractical when simultaneously acquiring data and controlling timing on a single computer.

Initial tests with water secondary discharges were singularly disappointing, and required reanalysis of both the concept and the materials. Examination of the MSDS for Amerex BC (sodium bicarbonate powder) revealed the addition of significant quantities of silicon oil to the sodium bicarbonate. This addition serves to make the powder effectively hydrophobic and prevents wetting by the water mist.

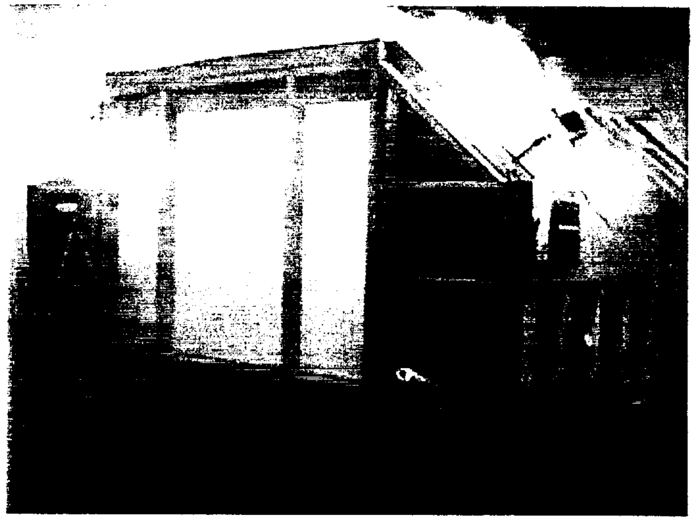
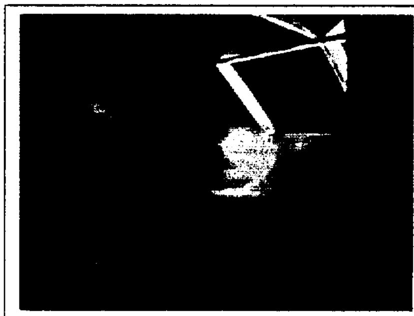
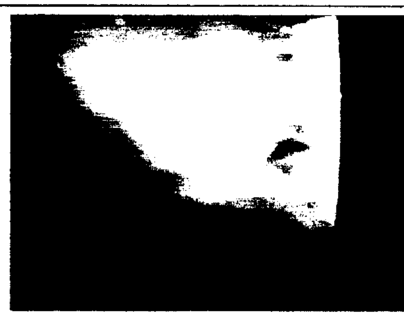
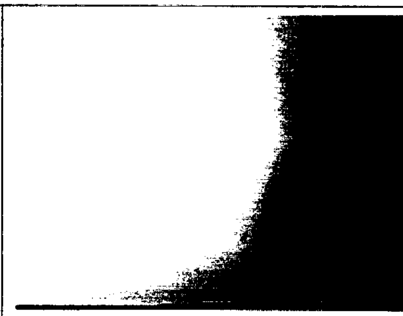


Figure 6. Test chamber at approximately 3 minutes after a failed test.

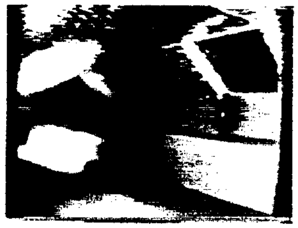
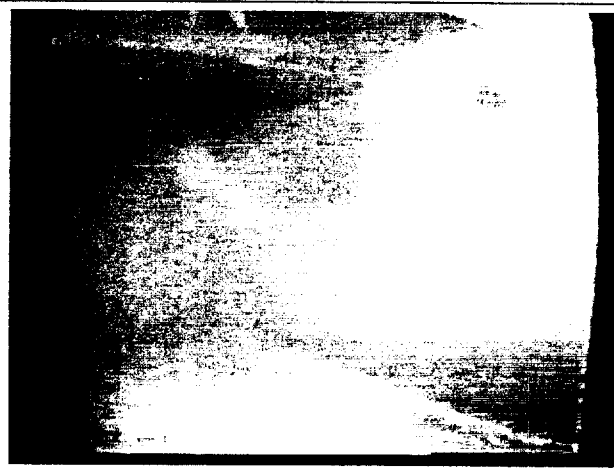
Figure 6 and Table 1 shows a video sequence where vision is totally obscured several seconds, and in fact minutes after discharge.

Table 1. Sequence from an unsuccessful test

		
Video Frame a. t=05	**Video Frame b. t=38**	**Video Frame c. t=3000**

Replacing the Amerex BC powder with commercial baking soda tested this theory. In Table 2 is a sequence of frames from Test 9. The difference between Video Frame c and Video Frame i clearly shows the difference in visability. It should be noted that in Test 9, the water discharge valve re-closed after discharging only 20% of the water charge.

Table 2. Sequence from the "proof of concept test"

 Video Frame d. t=-10	 Video Frame e. t=23	 Video Frame f. t=56	 Video Frame g. t=89
 Video Frame h. t=122		 Video Frame i. t=3000	

V. Interim Conclusions

Results to this point show that water can quickly remove some types of fire extinguishing powders. Conventional extinguishing powders, which are coated with Silicon Oil are not readily removed from the air by a water mist. In addition, the spray from the FAASV nozzles is probably less than optimum for removing powders, as it is clearly a large droplet spray and not in anyway a mist.

VI. Future Work

The primary optimization effort will be devoted to reducing the water droplet size by using a misting nozzle for distributing the water. Further testing using the surface treated powders will center on the use of surfactants to enhance the wetting ability of the water mist.

Dual Agent Test Program, Summary Sheet

Test Number	Date	Temp.(F)	Contents Bottle A	Bottle B	Bottle C	Bottle D	Delay Time	COMMENTS
1	1-May-98	72	Water 48 oz.	BC 3.5 lb.	BC 3.5 lb.	Water 48 oz.	100 ms.	Water discharge failed to washout suspended dry chemical. Visibility remained at zero indefinitely.
2	25-May-98	82			nitrogen	nitrogen	100 ms.	Used nitrogen in both bottles to test capacitor discharge levels. Low volt. (11v.) on capacitor two prevented bottle D from discharging.
3	26-May-98	82			nittrogen	nitrogen	100 ms.	Used nitorgen in both bottles to test capacitor discharge levels. Capacitor 1 registered 22v. Capacitor two registerd 11v. Both discharged.
4	26-May-98	85			Water 48 oz.	BC 3.5 lb.	100 ms.	Water discharge failed to washout suspended dry chemical. Visibility remained at zero indefinitely.
5	27-May-98	80			Water 48 oz.	BC 3.5 lb.	1000 ms.	Bottle D discharged pre-maturely due to capacitor malfunction.
6	28-May-98	75			BC 3.5 lb.	Water 48 oz.	500 ms.	Water discharge failed to washout suspended dry chemical. Visibility remained at zero indefinitely.

			Contents					
Test Number	Date	Temp.(F)	Bottle A	Bottle B	Bottle C	Bottle D	Delay Time	COMMENTS
7	28-May-98	80			BC 3.5 lb.	Water 70 oz.	500 ms.	Bottle C failed to discharge due to capacitor problem. Bottle D discharged 46 0z.water and retained 150psi.
8	28-May-98	83			BC 3.5 lb.	Water 60 oz.	1000 ms.	Water discharge failed to washout suspended dry chemical. Visibility remained at zero indefinitely.
9	29-May-98	78		BC 3.5 lb.		Water 60 oz.	500 ms.	Utilized Baking Soda in bottle B. Only 10oz. water discharged form bottle D but cleared visibility in 10 seconds.
10								
11								
12								